



Lunar Orbital Neutron Measurements Current Knowledge and Future Prospects

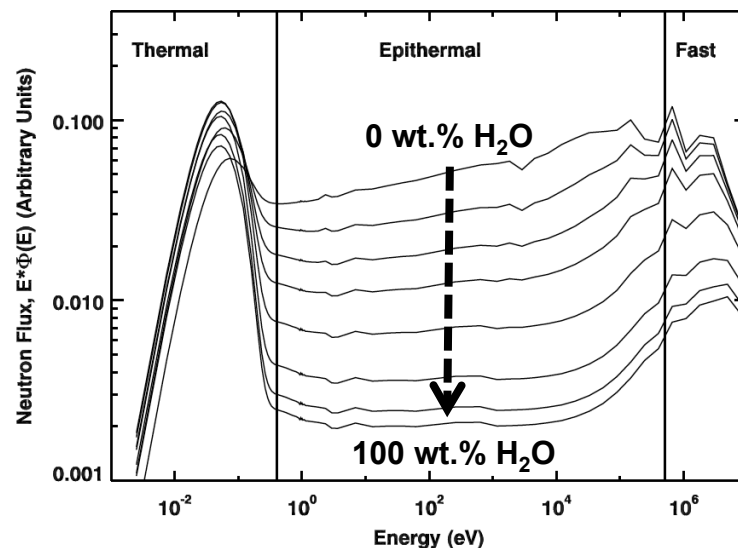
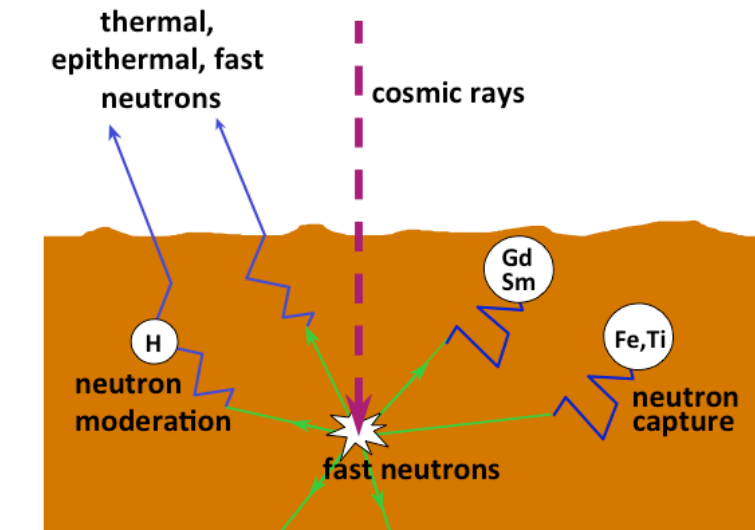
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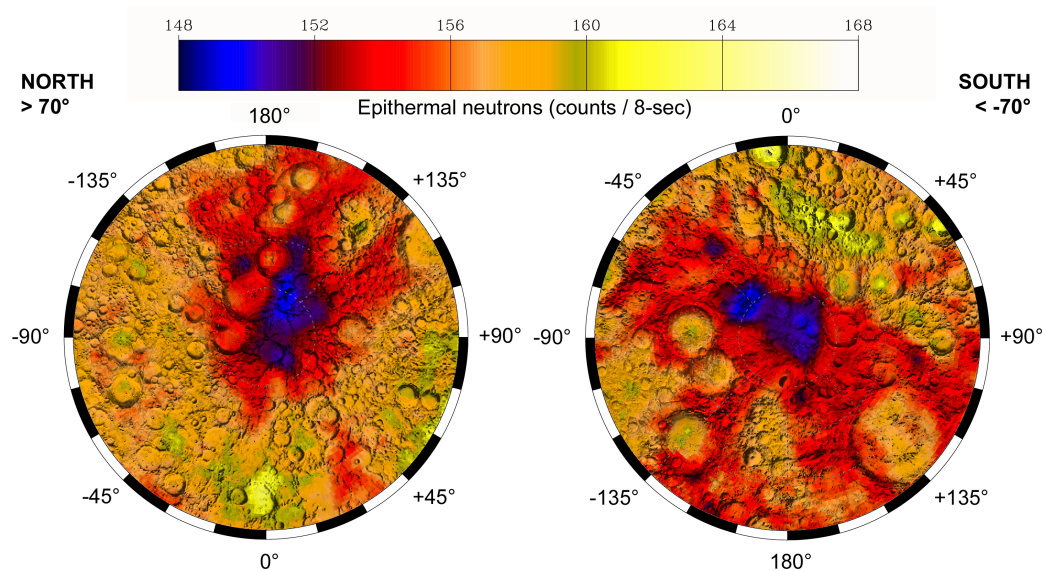
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Measuring Planetary Hydrogen



- Planetary neutron spectroscopy used to measure hydrogen concentrations on planetary surfaces.
- Epithermal neutrons provide strong measure of hydrogen concentration.
- For omni-directional sensors, spatial resolution is $\sim 1 - 1.5$ times spacecraft altitude.

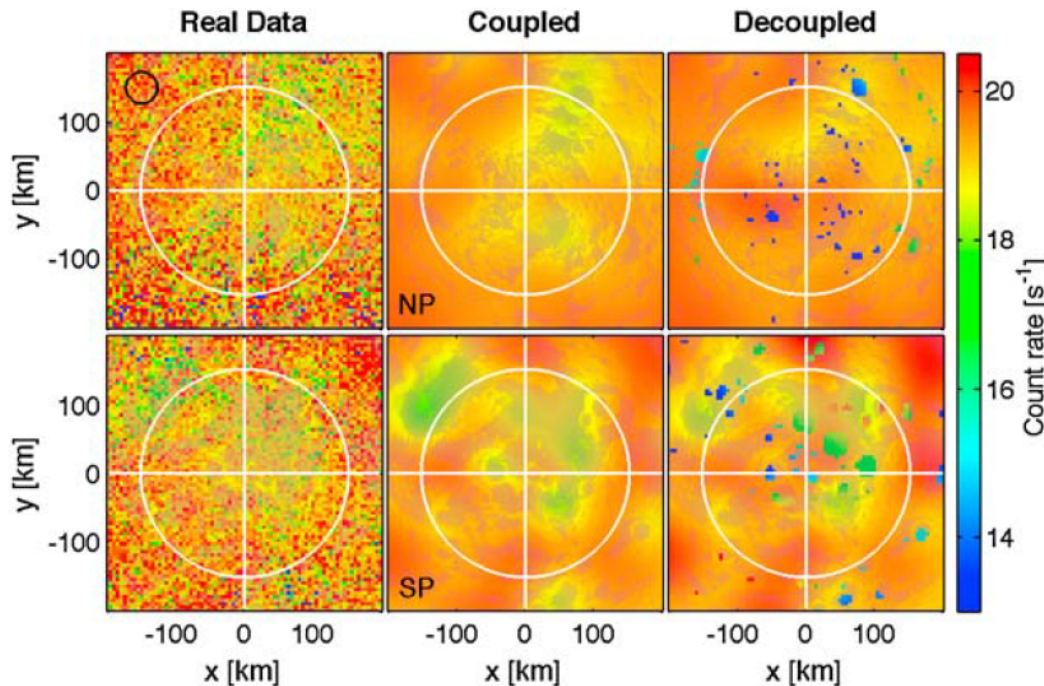
Existing Measures of Lunar Polar Hydrogen



Lunar polar epithermal neutrons measured by the Lunar Prospector Neutron Spectrometer (*Feldman et al.*, 2001).

- **Lunar Prospector (LP) epithermal neutrons**
 - **Broad spatial resolution**
- **Spatial reconstruction of LP data**
 - Result requires prior knowledge of PSRs
- **Surface Hydrogen at Shackleton crater?**
- **Collimated neutron measurements**
 - Small signal and large uncollimated background limit spatial resolution

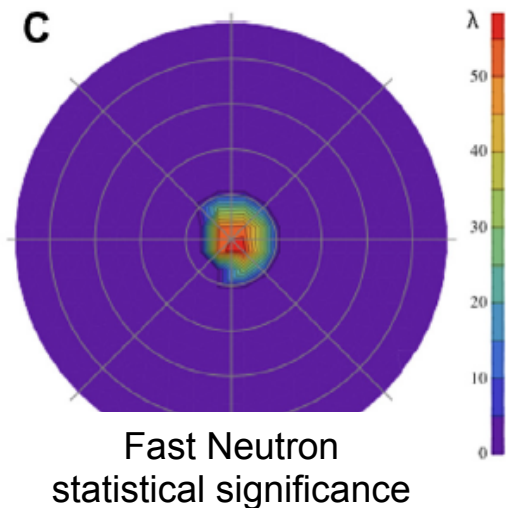
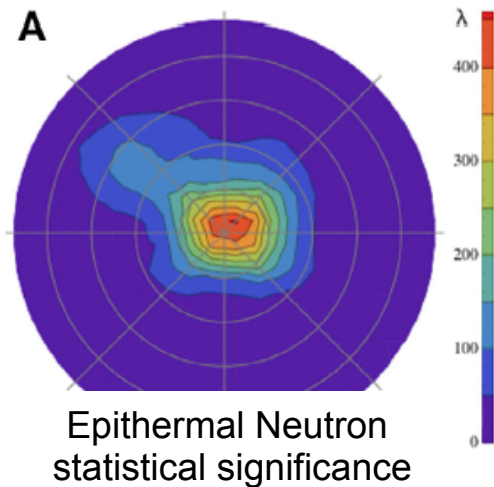
Existing Measures of Lunar Polar Hydrogen



Spatial reconstructions of LP epithermal neutron data (Eke et al., 2009; Teodoro et al., 2010).

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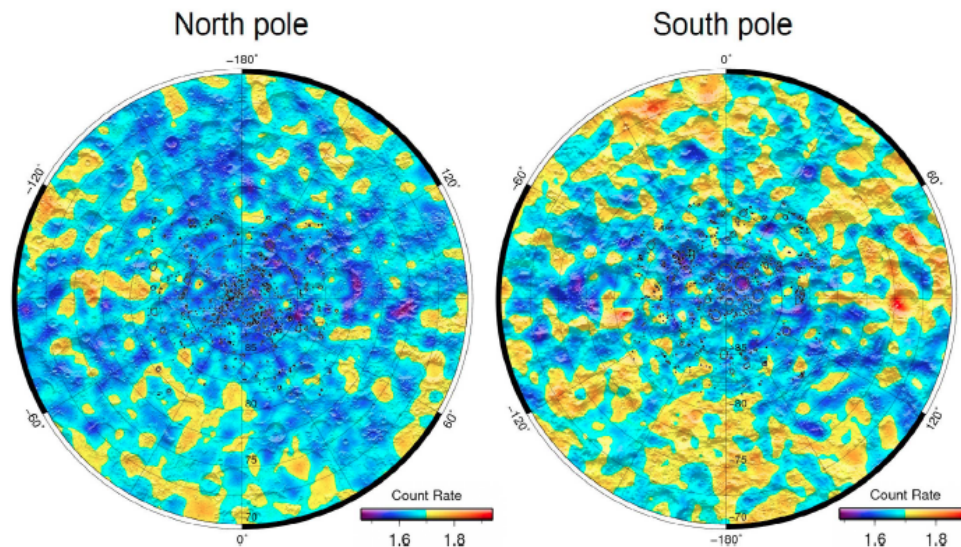
Existing Measures of Lunar Polar Hydrogen



Miller et al. (2014)

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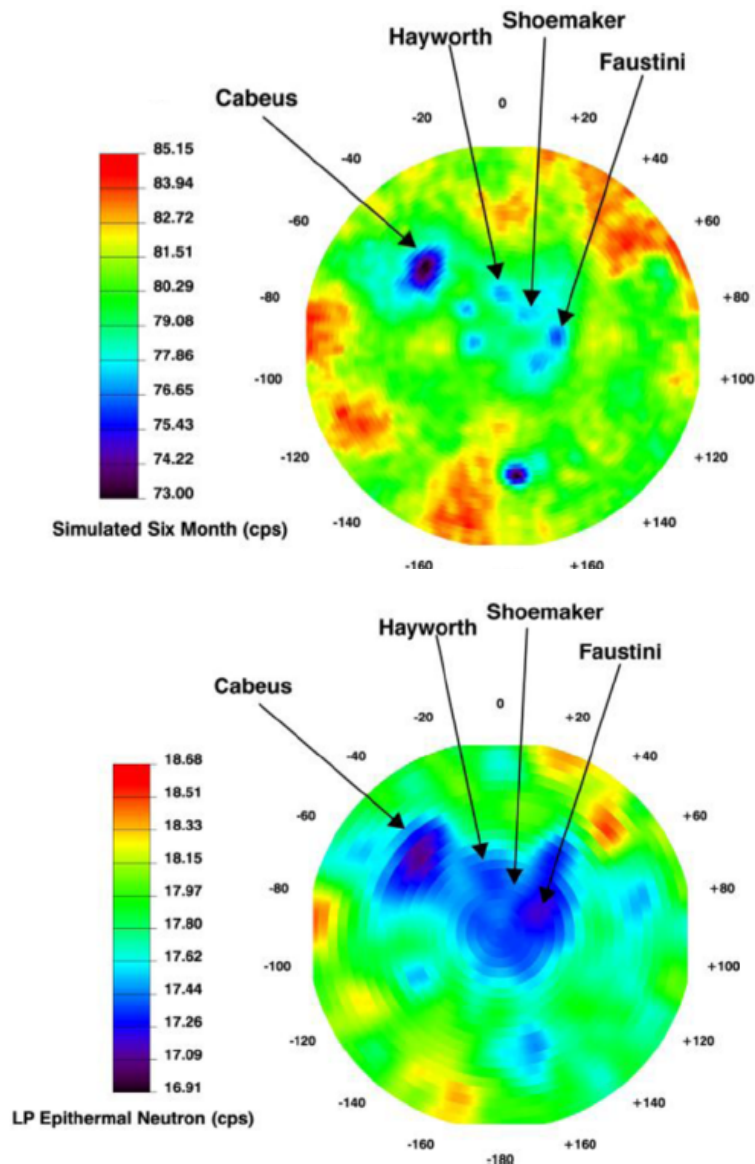
Existing Measures of Lunar Polar Hydrogen



Collimated epithermal neutrons from the Lunar Exploration Neutron Detector (*Mitrofanov et al.*, 2011).

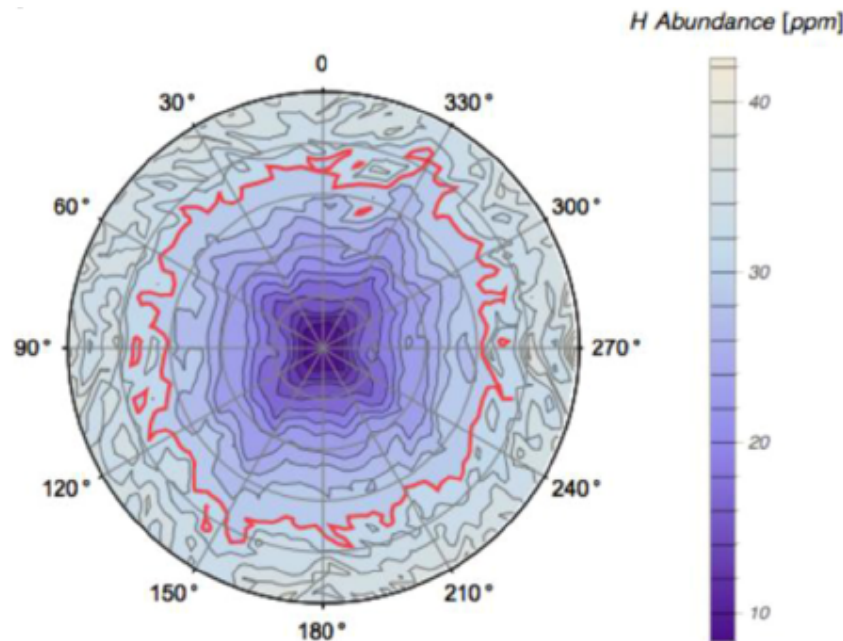
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Low-Altitude (~10 km) Neutron Measurements

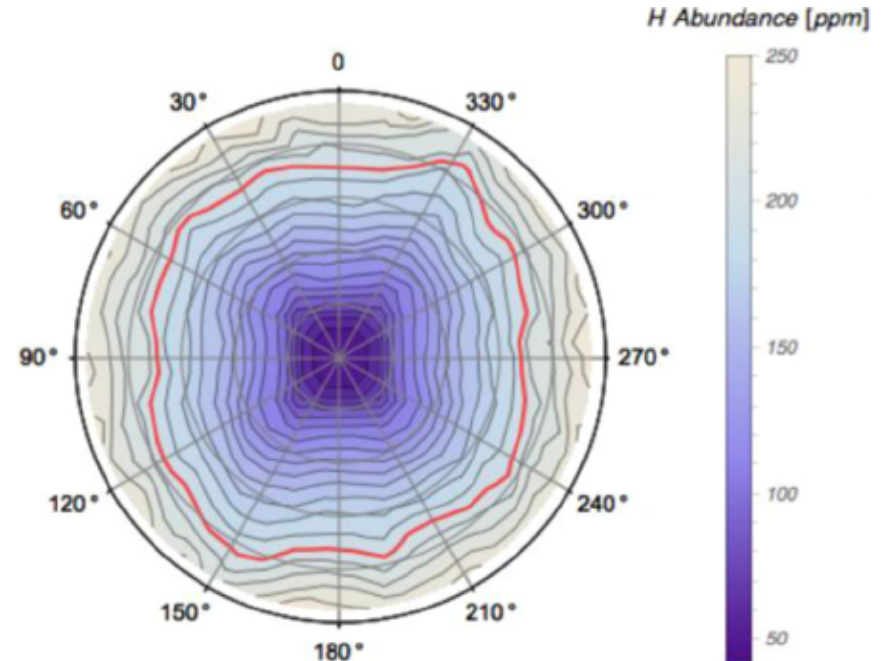


- Low-altitude data would obtain significantly improved measurements compared current “best measurements.”
- Require six-months of data collection using one-module NS.
 - Challenging to field on CubeSat.
- Four-module sensor would acquire measurements in three months.
 - Easily accommodated on small sat (i.e., 12U-like spacecraft.)

Detection Limits



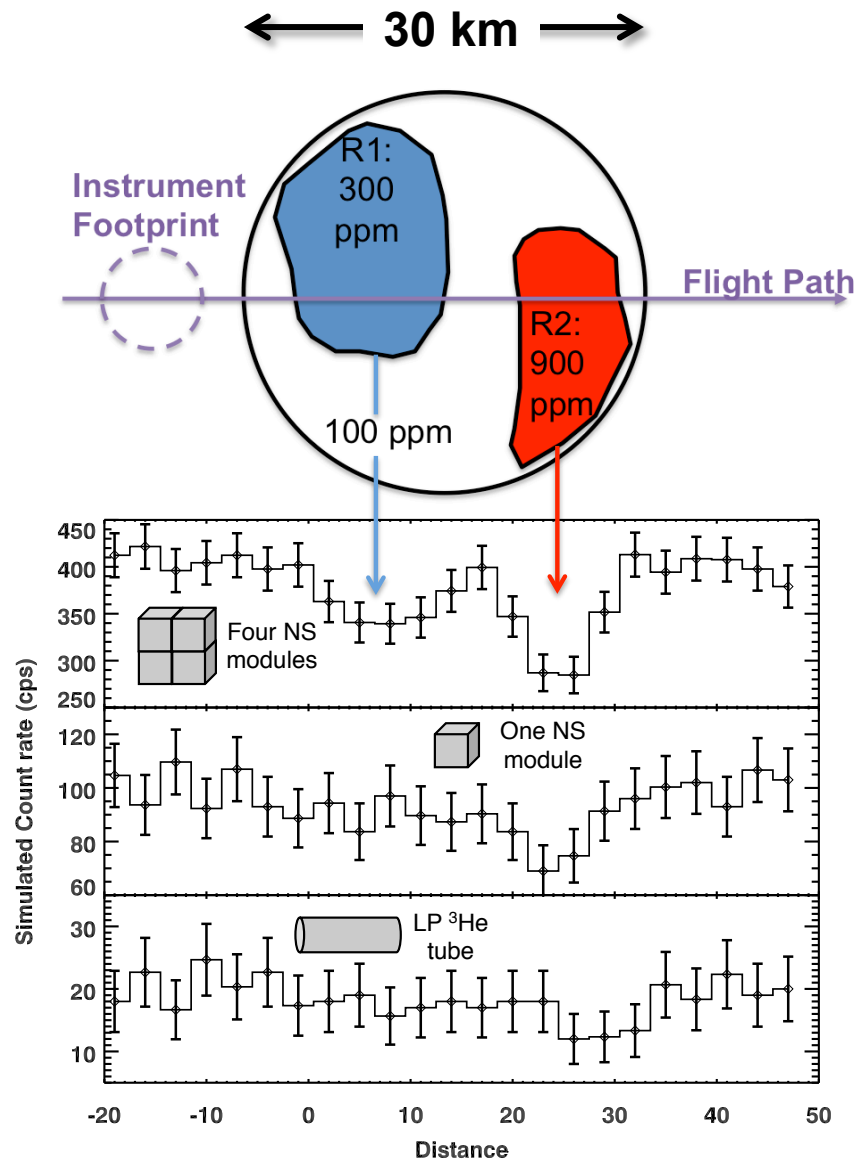
**Bulk hydrogen detection limit
(red contour 30 ppm)**



**Buried hydrogen detection limit
(red contour 200 ppm)**

- High-precision measurements provide robust bulk and buried-hydrogen detection limits across the entire pole.

Very-low-altitude Measurements (~5 km)



- Finish mission with few, very-low-altitude measurements.
- Four-module sensor can spatially resolve spatial heterogeneity within PSRs.
 - One-module or LP-like ³He sensor cannot resolve on single pass.
- Use as benchmark for spatial deconvolution, and for “ground truth” for higher-order deconvolution.